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A NOTE ON THE GALACTIC RADIATION EXPOSURE IN GEOMAGNETICALLY UNPROTECTED REGIONS OF SPACE

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SUMMARY PAGE

THE PROBLEM

Galactic radiation is anticorrelated to solar activity; i.e., the flux is highest at solar minimum and vice versa. This phenomenon is assumed to be caused by an interplanetary magnetic field which, depending in its intensity on solar activity, modulates the galactic radiation as it enters the solar system. Measurements during the Years of the Quiet Sun 1964-65 have greatly augmented our knowledge of the galactic spectrum at solar minimum, particularly in the low rigidity section, allowing now a more complete assessment of radiation exposure in space at a phase of the solar cycle when the galactic flux is at its maximum.

FINDINGS

The measurements indicate that the galactic flux definitely is modulated even at solar minimum, showing a strong depression of the differential flux at low rigidities. This has the reassuring consequence that the exposure of man in systems of low shielding (space suit, lunar excursion module) will not result in exceptionally high skin doses. This is in sharp contradistinction to the exposure from trapped radiation and solar particle beams where very steep depth dose gradients in the body behind low shield thicknesses always occur.

Though the recent measurements still do not reach far enough down on the rigidity scale to assess the exposure for very low shielding (0.1 g/cm^2), the strong depression of the differential flux toward lower rigidities would seem to allow a reliable extrapolation over the comparatively short rigidity interval not yet explored.

A conservatively high estimate for the galactic exposure is 50 millirads/24 hours for 2π incidence as it would hold, for instance, on the surface of the moon. The high LET fraction of this exposure cannot be reliably assessed because no good data on the low energy flux of secondaries are available. A conservatively low estimate is 5 to 8 per cent or 2.5 to 4 millirads/24 hours for the high LET dose.

Transferring the detailed experimental information on the life shortening of mice for chronic low and high LET irradiation to the galactic exposure of man in space leads to a factor of 0.2 in the sense that 100 days' exposure to the full galactic flux at solar minimum would shorten the residual life span by 20 days. An unknown quantity in this estimate is represented by the thin-down hits of heavy nuclei which cannot be assessed in the usual terms of dose equivalents.

INTRODUCTION

For manned space missions in near-Earth orbits, concern about the astronaut's radiation exposure centers on the radiation field of trapped protons and electrons in the South Atlantic Anomaly. Although only about 5 per cent of the total time in space on a Gemini type of multi-orbital mission is spent in scanning through the South Atlantic Anomaly, the accrued exposure from trapped particles in that area accounts for about 95 per cent of the total mission dose, thus lowering the contribution from galactic radiation to a negligible quantity. For deep space missions outside the magnetosphere the situation is quite different. On the one hand, there are no trapped particles; on the other hand, the galactic exposure is about ten times larger than that in a Gemini type orbit. Furthermore, since geomagnetic cutoff effects are absent outside the magnetosphere, the galactic spectrum extends to substantially lower energies.

Measurements with sounding rockets and satellites during the recent solar minimum (Years of the Quiet Sun 1964-65) have substantially augmented our knowledge of the galactic spectrum during the time solar modulation is minimal, i.e., the galactic flux at its maximum. It seems of interest to reassess, on the basis of these more complete data, the galactic radiation exposure of man in space. The following report is an attempt in this direction. It is limited strictly to this particular aspect and does not aspire to discuss the various theories and hypotheses concerning the origin of galactic radiation and its propagation in the interplanetary medium.

THE GALACTIC RIGIDITY SPECTRUM AT SOLAR MINIMUM AND MAXIMUM

In the discussion of radiation hazards on deep space missions of long duration which do not allow a quick abort and re-entry into the Earth's atmosphere in case of a major flare event, interest has centered, in the past, mainly on solar particle beams. Great efforts have been made toward interpretation of the rather limited body of information on the physical characteristics of flare produced particle fluxes in terms of tissue dosages for various shield systems. Since these studies by now should have created a thorough familiarity with the general spectral characteristic of flare beams and the quantitative aspects of shielding, it seems useful to point out, in a direct antithesis, the basically different conditions for galactic radiation.

It is quite obvious that man in space will never move about freely in "shirtsleeve" attire because of the need for a pressurized envelope of some kind. Therefore, space radiation spectra in the present context are of interest only above certain minimum energies or rigidities that are capable of penetrating the shield equivalents of a space suit, a vehicle, or a space platform as the case may be. If the discussion is limited momentarily to protons and alpha particles, which constitute the main components of the galactic particle flux, one arrives, for the shielding equivalents of typical space systems, at the minimum kinetic energies and rigidities required for penetration listed in Table I.

Table I

Minimum Kinetic Energies and Rigidities for Protons and Alpha Particles Required for Penetration of Typical Shield Thicknesses

Space System	Min. Shield. Equivalent, g/cm^2	Kinetic Energy, Mev		Magnetic Rigidity, Mv	
		Protons	Alpha Particles	Protons	Alpha Particles
Space suit	0.1	8.4	33.6	125	252
Gemini vehicle	0.2	12.3	49.2	152	303
—	0.5	20.5	82.0	197	392
—	1.0	30.1	120	240	492
Apollo vehicle	1.5	37.8	151	269	545
Permanent lunar base	2.0	44.2	177	290	588

The effects of shielding on the residual exposure of a human target differ basically for galactic radiation and solar particle beams. This is immediately seen if the positions of the minimum rigidities listed in Table I on the rigidity scale are compared in relation to the rigidity spectra of the two types of radiations. By using an appropriate scaling factor, the enormous difference in the instantaneous fluxes of the two radiations can be equalized and the rigidity spectra plotted in one graph as shown for protons in Figure 1. The critical rigidity interval from the lowest to the highest shield equivalent in Table I is indicated in Figure 1 by vertical arrows. One recognizes at once the basically different situation for the two radiations. Whereas very substantial flux fractions would be cut off from the solar particle beam by the shield thicknesses in question, thereby drastically reducing the residual flux and radiation level behind the shield, only negligible flux fractions from the galactic spectrum would be cut off.

Conditions are further complicated by the fact that for galactic radiation with the bulk of the flux centering on high and very high rigidities, the radiation exposure behind a shield is not determined by the residual primary flux only, but to a large measure also by secondaries produced in the local hardware surrounding man and in the body tissues themselves. As the flux of these secondaries and their secondaries of higher order gradually increases in the initial layers of a compact absorber, the tissue dose behind a shield actually increases with increasing shield thickness in the region of small thicknesses (so-called build-up phenomenon). It is seen, then, that an accurate quantitative assessment of the radiation exposure for galactic radiation requires a determination of the dose contribution from primaries as well as from locally produced secondaries.

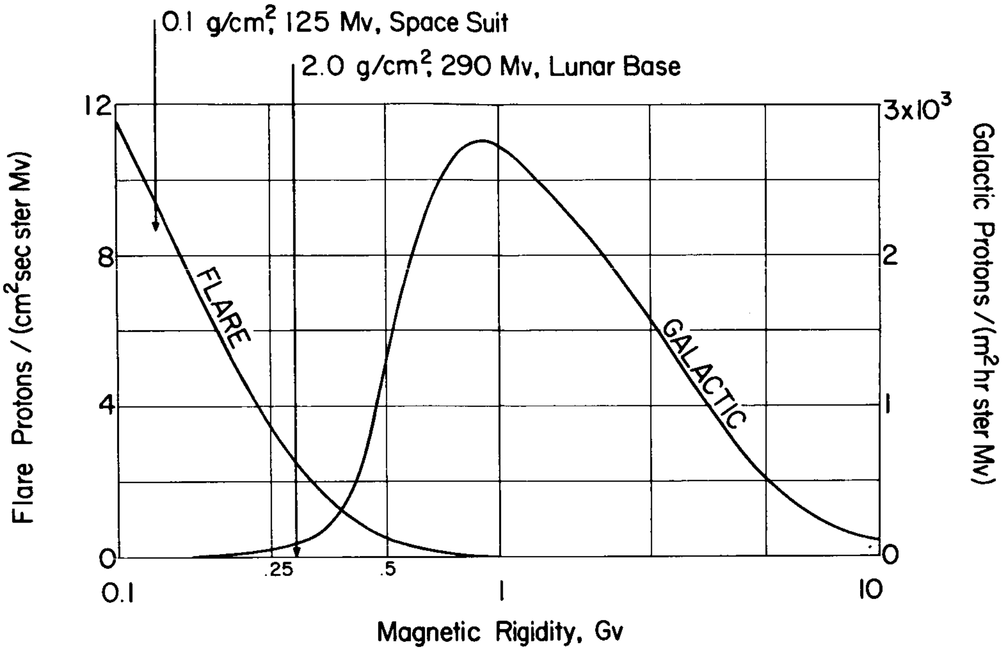

Figure 1

Comparison of the Differential Rigidity Spectra of Galactic Protons and of Protons of a Typical Solar Particle Beam

(Note great disparity of ordinate units differing by a factor of 36 million!) Galactic spectrum is based on the data of Freier and Waddington (1); flare spectrum pertains to event of 17 July 1959.

In a survey of the physical characteristics of the primary radiation, the most important phenomenon is the large long-term variation of the galactic flux in correlation with the solar cycle. While the detailed mechanism responsible for this variation is not fully explored yet, many lines of evidence point to an interplanetary magnetic field created by the solar wind as the cause. This field, especially strong during an active sun, exerts a screening influence predominantly affecting low rigidity particles. As this effect is greatly reduced at solar minimum, the galactic rigidity spectrum shows greatly enhanced flux levels in the low rigidity section at that time. Experimental information is still incomplete, yet satellite data obtained during the Years of the Quiet Sun 1964-65 seem to have settled at least one important issue. It appears now to be well established that the interplanetary magnetic field and its influence on the galactic flux, though greatly reduced, do not vanish altogether at solar minimum. As a consequence, the low rigidity galactic flux is still modulated at solar minimum to such a degree that the differential flux drops steeply toward low and very low rigidities.

A number of experimenters have reported on measurements of the low rigidity galactic flux at or near the solar minimum between Cycle 19 and 20. While rigidity seems to be the preferred independent variable, results have also been presented in terms of kinetic energy. Since either magnitude does not convey an immediate idea as to depth of penetration, the sophisticated discussion among astrophysicists on the merits of the two ways of plotting flux spectra is not of special interest in the present context. The rigidity spectrum of galactic protons at solar minimum that is shown in Figure 1 is based on the measurements by Freier and Waddington (1) and is in satisfactory agreement with the spectrum reported by Ormes and Webber (2) and by Gloeckler (3), who presented his data in terms of kinetic energy.

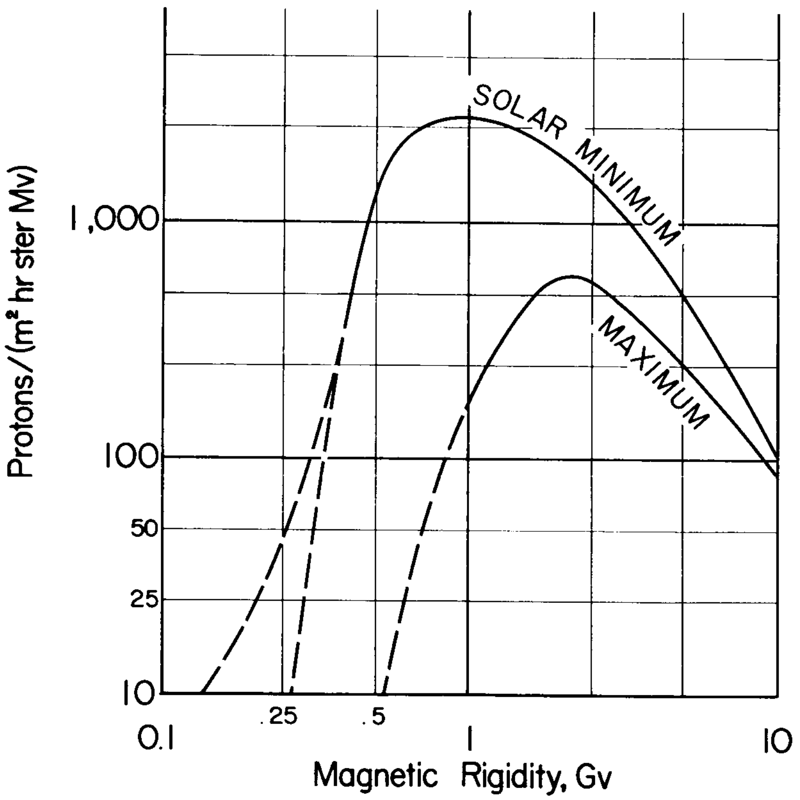

Figure 2

Differential Rigidity Spectrum of Galactic Protons at Solar Maximum and Minimum

Solid sections of curves are based on data of Freier and Waddington (1) for solar minimum and of Webber (4) for solar maximum. Broken sections indicate extrapolations.

The galactic spectrum of Figure 1 is replotted in log log coordinates in Figure 2, together with the spectrum at solar maximum as reported by Webber (4). The sections in broken lines in both spectra indicate tentative extrapolations into the region of very low rigidity where direct measurements are still lacking. The important fact demonstrated with Figure 2 is that the steep drop of the differential flux below about 1 Gv rigidity is maintained at solar minimum. This gives the assurance that in space systems of low shielding, even at solar minimum, no abnormally high skin doses in a human target will occur. This is quite different from exposure conditions for trapped radiation and solar particle beams.

TISSUE DOSAGES FROM GALACTIC RADIATION AT SOLAR MINIMUM AND MAXIMUM

In the present context where interest centers on the radiation exposure of man, flux and rigidity data have to be expressed in terms of absorbed doses in tissue. As mentioned before, the tissue dose in a human target within an enclosure is to a large measure determined also by secondaries produced locally in the material of the enclosure and in the body tissues themselves. The bulk of these secondaries originates in extremely complex chains of nucleonic and photon-electron cascades starting from nuclear collisions of primaries of very high energies. While the different types of cascade processes involved have been investigated extensively both theoretically and experimentally, a combined quantitative analysis leading to the total ionization dosage from all secondaries has never been attempted. The same statement holds for direct measurements of the build-up of secondaries in compact absorbers for primary galactic particles. However, information is available on the build-up of the total ionization of the galactic radiation in the Earth's atmosphere. By expressing the residual air layer overhead in terms of its mass equivalent in g/cm^2, these data can serve at least as a first approximation of what the corresponding build-up in a compact scatterer would look like.

The most comprehensive measurements of the build-up in the Earth's atmosphere have been carried out by Neher and co-workers in continuation of the early pioneer work of Millikan. Figure 3 is based on data from balloon flights close to the geomagnetic pole reported by Neher and Anderson (5). As charged particles traveling parallel to the lines of magnetic force do not suffer any deflection, these particular measurements can be considered as representative for the total ionization as it would develop in the absence of any magnetic field. In Neher's original data the total ionization is expressed in ions per cc of air per atmosphere; in Figure 3 data are converted into tissue dose rates in millirads/24 hours. It should be mentioned in this connection that Neher's measurements were carried out with a stainless steel ion chamber filled with argon under high pressure. That means the chamber system was not tissue equivalent and the readings actually should not be expressed in terms of absorbed doses in millirads. This objection holds especially with regard to the representation of the dose contribution from the neutron component in view of the hydrogen content of tissue. Since other lines of evidence indicate that neutrons contribute less than 10 per cent to the total dose, however, the conversion to absorbed tissue doses in millirads appears acceptable for a first approximation estimate.

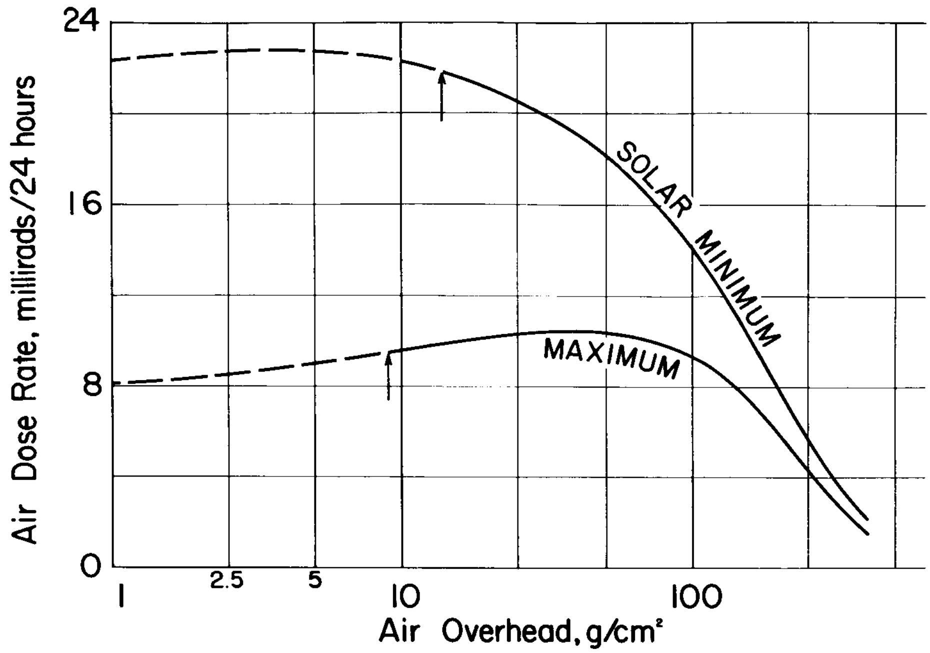

Figure 3

Total Ionization of Galactic Radiation in the Earth's Atmosphere at Solar Maximum and Minimum

Solid sections of curves are based on data of Neher and Anderson (5). Broken sections indicate extrapolations.

A more serious limitation of Neher's data derives from the fact that they were obtained with balloons and therefore do not extend to zero thickness of air overhead, i.e., to conditions of free space. In fact, they end at the rather large minimum overlay of about 10 g/cm^2 of residual atmosphere. This represents a much heavier minimum shield thickness than even a heavy space platform would provide, not to mention an Apollo type vehicle or other still lighter space systems. However, with the low rigidity section of the galactic spectrum now known, the basic trend of the curve of the total ionization toward zero thickness can be predicted at least to the extent that it must flatten toward lower thicknesses and eventually decrease again. The broken part of the upper curve in Figure 3 indicates an extrapolation based on this conclusion.

Another problem that arises if Neher's data are used for estimating the build-up in a compact absorber derives from the fact that the data hold for the rarefied air of the upper atmosphere, i.e., for a medium of very low density and of a different atomic composition than the materials of a vehicle frame or a space platform. A detailed discussion of the quantitative aspects of the possible errors from these sources is beyond the scope of this treatise. It may suffice to say that a factor of 2 for the dose increase due to the various intensifying effects in the transfer in question would seem to lead to a conservatively high estimate of the true dose. Applying this factor 2, one would obtain, then, a maximum total dosage from galactic radiation at solar minimum of about 50 millirads per 24 hours. It should be remembered that this estimate is based on measurements in the Earth's atmosphere, i.e., for 2π incidence of the primary radiation since the planetary body of the Earth shielded, in Neher's measurements, the entire lower hemisphere. Correspondingly, the dose of 50 millirads/24 hours would hold only for similar geometry in space as, for instance, on the lunar surface, yet would have to be multiplied by another factor of 2 for conditions of free space with 4π incidence of the primary flux. Since galactic exposure is of interest only for extended tours of duty and since such tours, in the more immediate future, are likely to occur mainly in lunar exploration, the evaluation of the exposure hazard for 2π conditions seems appropriate.

REM DOSE EQUIVALENT OF GALACTIC RADIATION EXPOSURE

A full dosimetric evaluation of any radiation exposure requires conversion of absorbed dose into the dose equivalent, taking into account the LET spectrum of the radiation. In the present analysis this is of special importance and poses special problems because of the heavy component of galactic radiation. The rigidity spectra in Figures 1 and 2 pertain only to the proton component of the galactic flux whereas the data on the total ionization, on which Figure 3 was based, included the contributions from all primaries and secondaries. For primaries heavier than protons and alpha particles, available flux and spectral data are much less well defined. As far as the limited information allows quantitative conclusions, the rigidity spectra of all nuclear species heavier than protons appear to have the same basic configuration in the sense that all spectra can be generated from the alpha spectrum by applying a constant reduction factor for each Z component.

The rigidity spectrum for the alpha component at solar minimum as it can be drawn as a compromise between the somewhat different data of Freier and Waddington (l.c., 1) and Ormes and Webber (l.c., 2) is shown in Figure 4. The same curve, then, would hold also for all heavier nuclear species if the ordinate values are changed by the flux ratios listed in the last line of Table II taken from a survey by Waddington (6). Since the experimental determination of individual Z-numbers in the total heavy spectrum from Z = 3 to 28 is quite difficult, data on the heavy flux are usually presented in terms of broader Z classes. Adopting this method, we divide in the following analysis the flux components heavier than He in three classes, comprising the Z numbers from 3 to 9, from 10 to 19, and from 20 to 28 using as the corresponding group representatives C-nuclei (Z = 6), Ne-nuclei (Z = 10), and Ca-nuclei (Z = 20). If the individual LET/E function of the group representative is applied to the flux value for each group, the contribution of the group to the total ionization can be determined with satisfactory accuracy. The results of this evaluation are listed in the next to last line of Table II, which shows also the contributions of the proton and alpha components. It is seen that the dose fractions from all primaries combined furnish a total of slightly less than 12 millirads/24 hours. The difference between this value and the grand total of the ionization dosage of 50 millirads/24 hours, i.e., 38 millirads/24 hours, represents the dose contribution from secondaries.

Table II

Particle Spectrum of Primary Galactic Radiation

Element		H	He	C	Ne	Ca
Atomic Number Z:		1	2	6	10	20
LET,	Minimum	0.18	0.73	6.6	18	73
kev/micron T	Maximum	85	240	964	1420	2790
Primary ionization dose, millirads/24 hours		3.9	3.2	2.0[a]	1.1[b]	1.6[c]
Rigidity flux ratio to He component		--	1.0	0.075[a]	0.015[b]	0.0054[c]

a: For Class Z = 3 to 9; b: For Class Z = 10 to 19; c: For Class Z = 20 to 28

Table II also lists the maximum and minimum LET values of all nuclear components of the primary galactic radiation. Adherence to standard practice in determining dose equivalents would require the assignment of appropriate RBE factors to the dose fractions according to their respective LET values. For the present purpose of a first approximation estimate of the radiation exposure from galactic radiation, a simplified approach would seem acceptable by dividing the total dose merely into a low-LET and a high-LET fraction. Accordingly, the dose contributions from all primary protons, alpha particles, and C-nuclei plus that from all secondaries regardless of origin are considered in the following analysis as of low LET, with the high-LET fraction containing solely the contributions from the Ne and the Ca group. Admittedly, this simplified classification overrenders the low-LET dose fraction since the nuclei in question spend, in the terminal parts of their ionization ranges, a certain small fraction of their energy at high LET. A similar overestimate of the low-LET dose fraction is made by considering all secondaries as low-LET radiation. Here again, those protons and alpha particles among the secondaries that reach the end of their ionization ranges produce a certain fraction of their ionization at high LET.

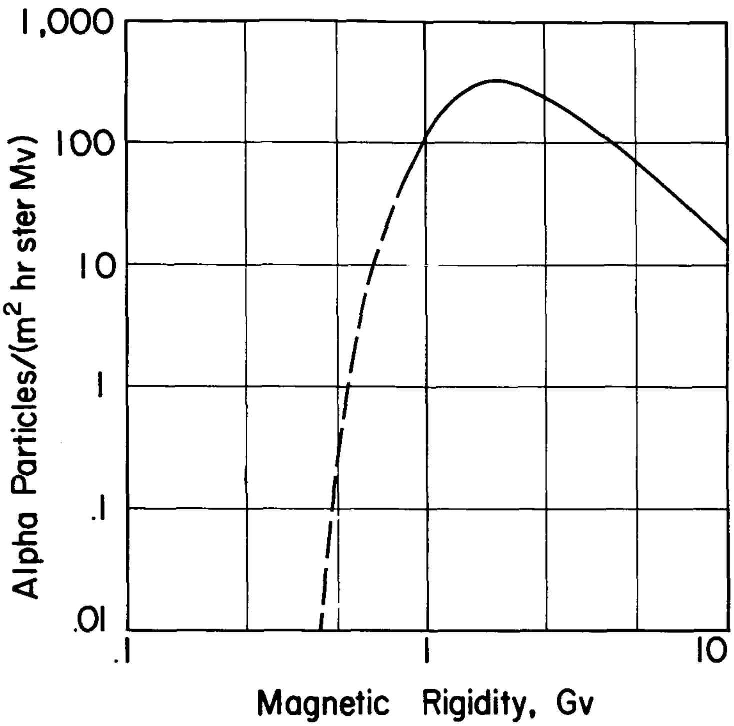

Figure 4

Differential Rigidity Spectrum of Galactic Alpha Particles at Solar Minimum

Solid section of curve is compromise between the data of Freier and Waddington (1) and Ormes and Webber (2). Broken section indicates extrapolation. The spectrum also holds for all components heavier than He if ordinate values are reduced by the factors listed in the last line of Table II.

The two biases in question which favor the low-LET dose fraction seem acceptable, if not desirable, in view of the fact that protons of very high energy, which contribute quite sizeably to the total dose of galactic radiation, are known to have a relative biological effectiveness (RBE) smaller than 1.0 due to their extremely low LET. Though the two counteracting influences could not be expected to balance out quantitatively, it seems appropriate to enter them in the LET account as compensating items.

Accepting the just-proposed LET breakdown of the galactic ionization dosage, one arrives, according to the dose fractions in Table II, at a low-LET dose of 47.3 millirads/day and at a high-LET dose of 2.7 millirads/day.

LIFE SHORTENING EFFECT OF GALACTIC EXPOSURE IN FREE SPACE

It is quite obvious that a radiation exposure of 50 millirads/day (or even twice that much for 4π incidence) could not possibly produce any acute radiation effects in man. What we are dealing with is clearly a low-dose long-term exposure that would cause concern only if extended or repeated periods of exposure in the range of months or years were involved and only if the inconspicuous effects of late chronic damage were to be considered. In other words, we are anticipating for the moment a future and more advanced state of space exploration where lunar colonization or manned interplanetary missions have become reality involving people in extended or repeated tours of duty.

Two types of long-term damages from chronic exposures to low doses are in the foreground of interest: shortening of life time and increased incidence of leukemia or malignancy in general. With regard to their statistical manifestation in exposed populations, the two types of damages differ basically. Malignancy is strictly a yes-or-no type effect for the individual, manifesting itself statistically in terms of the percentage of individuals striken. In contradistinction, shortening of life span affects all members of the exposed population although with a certain statistical spread in the quantity of effect for the individual. As a consequence of this basically different mode of response, data on life shortening are technically much more easily obtained in animal experimentation than on incidence of malignancy.

To be sure, direct human data on life shortening due to chronic irradiation are scarce (7). Studies on people professionally exposed to low levels of radiation such as radiologists carry a major uncertainty in the assessment of accumulated dose. It therefore seems a preferable approach to base estimates for man on the rather detailed information on life shortening by radiation in mice, accepting as the lesser disadvantage the uncertainty due to the essentially unproven assumption that the two species, man and mouse, show the same sensitivity in terms of normalized mean natural life spans.

Table III summarizes the essential information on the life shortening effect of ionizing radiation on mice converted to man by using the above-mentioned normalization of the greatly different mean natural life spans. The essential finding for application to exposures to galactic radiation is that low LET radiation shows a large recovery factor, lowering the life shortening from 12 to 3 days/rad if the dose rate drops below 1 rad/day. For high LET radiation no such recovery phenomenon exists, and the circumstance that galactic radiation exposure takes place at a low dose rate does not introduce any alleviating factor for the high LET dose fraction. The application of the basic data of Table III to the galactic radiation exposure at solar minimum is shown in Table IV. It is seen that 30 days of lunar duty at solar minimum would produce a shortening of the life span of about six days. In other words, the life shortening effect would equal about 20 per cent of the duty time. While this

Table III

Best Present (1966) Estimates for Life Shortening of Man from Exposure to Ionizing Radiation

Type of Radiation	Life Shortening, days/rad	
	Acute Exposure	Chronic Exposure
Low LET (Electrons, x- or gamma rays)	12	3
High LET (Low-E protons or neutrons, medium and high-E heavy nuclei)	24	24
Extremely high LET ("Microbeams" of heavy nuclei enders)	?	?

Table IV

Life Shortening of Man for 30-Day Lunar Duty at Solar Minimum

Component	Type	Dose Rate, millirads/day	30 Day Dose, rads	Life Shortening, days
Primary H, He, and C-nuclei and all secondaries	Low LET	47.3	1.42	4
Primaries $Z \geq 10$	High LET	2.7	0.08	2
		Total life shortening:		6

value can be assumed to represent a conservatively high estimate, it would seem to constitute a reasonable basis to work from if official or forensic problems of adequate compensation for hazardous duty are to be settled.

Though the estimate of long-term damage to man from galactic radiation arrived at above would seem a moderate price to pay in comparison to the more serious risk from other causes, it should also make it sufficiently clear that the galactic radiation exposure in space is by no means negligible for more extended mission times. This is so not only because the background level of ionizing radiation in space is about 100 times larger than on the Earth, but more so because the radiation exposure in space contains a sizeable high LET dose fraction which is known to show no time factor and no recovery.

A cause of particular concern is the phenomenon of the so-called enders or thin-down hits of heavy nuclei. They represent a peculiar type of radiation exposure that is best described with the term microbeam. The maximum LET values listed in Table II for the heavy components convey an idea of the magnitude of local radiation exposure in the microstructure of tissue which results from traversals of such nuclei passing through the so-called Bragg peak, i.e., through the maximum LET shortly before they come to rest. Cellular dosages in the thin-down sections of heavy nuclei reach the level of several thousand rads. The effectiveness of this peculiar type of radiation exposure for long-term damage such as life shortening is entirely unknown, as indicated in Table III by the question marks in the last line.

As the phenomenon of thin-down hits is a unique characteristic of the primary galactic radiation and cannot be studied in total body exposure in terrestrial laboratories, the mode of action on living matter is not well understood at present. Opinions differ especially as to the general effects in the mammalian organism from such "microbeam" exposures. Agreement does seem to exist among radiobiologists that this type of radiation exposure cannot be dealt with in the usual terms of RBE factors or dose equivalents for total body exposure. The problem has been discussed repeatedly in the literature (8-11), and the debate shall not be reopened here. It should be pointed out, however, that a space vehicle on an interplanetary mission or a lunar laboratory would seem ideal facilities for carrying out long-term biological experimentation with heavy nuclei. For such experiments it is interesting to note that the frequency of thin-down hits per unit volume of tissue shows a strong transition with a maximum developing at comparatively great depths in the target. The pertinent relationship is demonstrated in Figure 5. It shows the distribution of enders in a semi-infinite slab of tissue for unidirectional beams at right angle incidence. It is seen that the local frequency of enders, after a steep initial rise, passes through a broad maximum which develops for nuclei of different Z at different depths in an inverse fashion with the maximum for C-nuclei ($Z = 6$) found at 12 g/cm^2 depth and that for Ca-nuclei ($Z = 20$) at 3.5 g/cm^2. These data indicate that, depending on the specimen used and the reaction studied, an appropriate exposure geometry applying interposed moderating layers of material can substantially increase the enders dose at the point

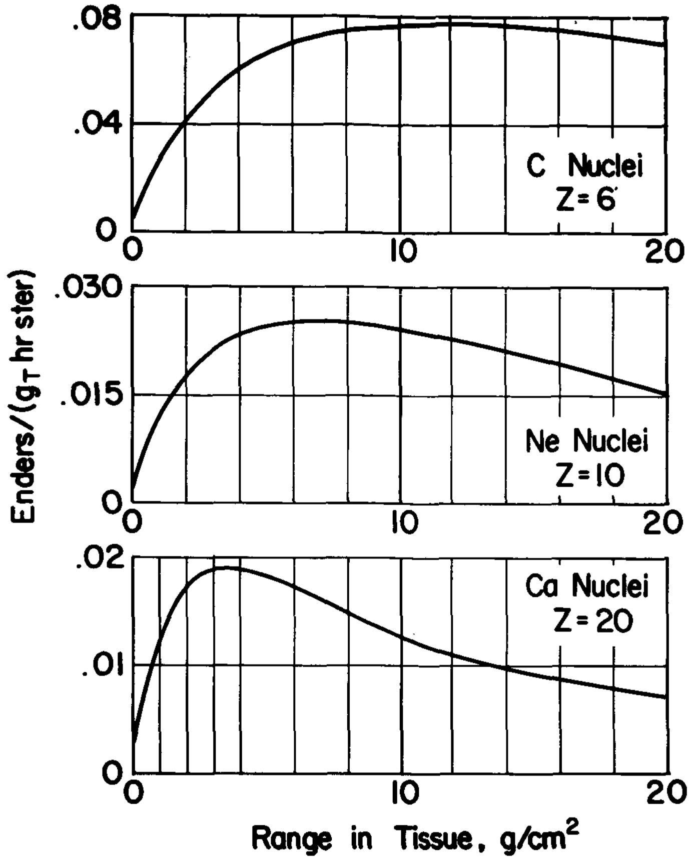

Figure 5

Depth Distribution of "Enders" or Thin-Down Hits from Heavy Nuclei in Semi-Infinite Slab of Tissue

Z-numbers are group representatives as explained in Table II.

of interest. Biological experimentation of this type, preferably with mammals in order to allow reasonable inferences to man, would seem the single most important task to be tackled before the galactic exposure hazard to man in space can be completely assessed.

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13. ABSTRACT

Measurements of the galactic flux at low rigidities during the Years of the Quiet Sun 1964-65 indicate that the galactic radiation is still modulated at solar minimum with the differential flux at low rigidities strongly depressed. Thus it is assumed that, in space systems of low shielding, no exceptionally large skin doses in a human target will result. This is quite different from that occurring from trapped radiation and solar particle beams. A conservative estimate for the total dose from galactic radiation at solar minimum including secondaries for 2π incidence is 50 millirads/24 hours with 5 to 8 per cent of this dose produced by high LET components. If life shortening is used as criterion for long-term effects, the quoted exposure corresponds to a factor of 0.2 in the sense that 100 days of exposure would shorten the residual life span by 20 days.

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Galactic radiation exposure						
Rigidity spectra of galactic flux components						
Long-term effects of galactic radiation on man						

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